Modeling and Mitigating Spatial Disorientation in Low g Environments

Completed Technology Project (2007 - 2011)

Project Introduction

Original Aims: The goal of this industry-university research and development project is to extend Alion's spatial disorientation mitigation software -- originally developed for aeronautical use -- to NASA's space applications including the Shuttle, CEV (crew exploration vehicle), Altair, and Mars exploration missions. Alion's Spatial Disorientation Analysis Tool (SDAT) was designed for post hoc analyses of aircraft trajectory data from U.S. Navy, Air Force, and National Transportation Safety Board (NTSB) mishaps to determine the presence or absence of vestibular spatial disorientation (SD). SOAS (Spatial Orientation Aiding System) is a real-time cockpit aid that has been evaluated in simulators with rated pilots. Both tools incorporate models of the vestibular system and assessor heuristics to predict the epoch and probability of an SD event such as Leans, Coriolis, or Graveyard Spiral illusions, as well as any other significant disparities between actual and perceived pitch attitude (somatogravic), roll rate, or yaw/heading rate. SOAS assesses multi-sensory workload to determine the types of countermeasures to trigger and when to trigger them. This project will: 1) Enhance the utility of SDAT/SOAS by including appropriate mathematical models for vestibular and visual sensory cues, and CNS (central nervous system) gravito-inertial force resolution into perceived tilt and translation estimates from Massachusetts Institute of Technology's (MIT's) Observer model, and revalidating it using existing aeronautical data sets. 2) Extend the models to describe 0-G, Shuttle, and Altair landing illusions, validating the models using Shuttle and Altair simulator data sets, and current theories (e.g., ROTTR). 3) Extend SDAT/SOAS to consider multiple visual frames of reference, the effects of visual attention and sensory workload, and the cognitive costs of mental rotation and reorientation. The enhanced SDAT/SOAS from Aims 1-3 will be validated via simulator experiments.

Key Findings: During the project's fourth year, we focused on: merging MIT's Observer model with Alion's SDAT; enhancing SDAT with N-SEEV (noticing-salience, expectancy, effort, and value) and with three new illusion models, verification tests, and comparisons of analytical results produced by SDAT and Observer; validation of SDAT with anonymous data sets of helicopter pilots who experienced SD; and administering an Institutional Review Board (IRB)-approved Space Shuttle spatial orientation survey.

Observer was 'packaged' as a DLL (dynamically linked library) within SDAT. SDAT users can select whether they wish to use Observer algorithms for predicted perception, or SDAT's algorithms. While Observer may be more physiologically accurate, Observer requires data sets to be of a fixed rate and fairly high frequency (10-100 Hz). Unfortunately, actual vehicle flight data recordings rarely meet these requirements. In addition, Observer does not account for misperceptions due to sub-threshold motions, which are critical to many SDAT illusion models. Therefore, we give users the option to select Observer or SDAT algorithms for attitude perception predictions.

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SDAT has also been enhanced with a pilot attention model called N-SEEV. N-SEEV elevates applied countermeasures when SDAT predicts that the pilot is suffering from SD and has not attended to a lower level of countermeasures. We created an updated version of SDAT's user manual and delivered SDAT and its user manual to the National Space Biomedical Research Institute (NSBRI). We did not undertake an experiment to validate the newly enhanced SDAT because we could use existing data sets plus the new ones acquired from our anonymous source of helicopter data sets. We also judged that a simulator validation experiment would use resources needed to do the best possible job of integrating Observer into SDAT.

FORT (frame of reference transformation) tool cost scores were not integrated into SDAT. The FORT tool remains a separate stand-alone tool. We performed additional FORT tool validation, and submitted an article for the Human Factors Journal.

We received 40 usable survey responses, analyzed the data from the 71 missions in the responses, and submitted an article to Aviation, Space, and Environmental Medicine reporting our method and results. We also sent de-identified data to our customer, NASA-Johnson Space Center (JSC's) Dr. Jacob Bloomberg, and will make the full set of de-identified data available to anyone who wishes it.

Anticipated Benefits

An important goal of this research and development project was to enhance Alion's spatial disorientation analysis tool (SDAT) and spatial orientation aiding system (SOAS), and MIT's Observer human perception model, so that the combined system accurately detects and classifies spatial disorientation events, and triggers the appropriate countermeasures for the situation. The combined system could be useful for aircraft pilots, space travelers, accident investigators, flying safety offices, and physiologists. This wide range of applicability is due to the intentional design of the system's components (i.e., SDAT, SOAS, & Observer) to be useful for post hoc analyses and for in-cockpit pilot aiding.

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Organization:

National Space Biomedical Research Institute (NSBRI)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Principal Investigator:

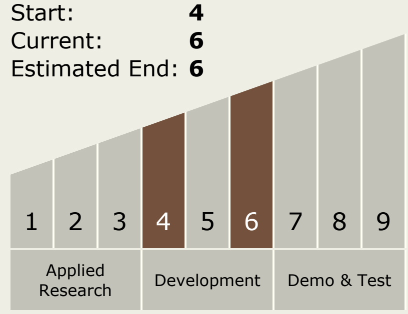
Ron Small

Co-Investigators:

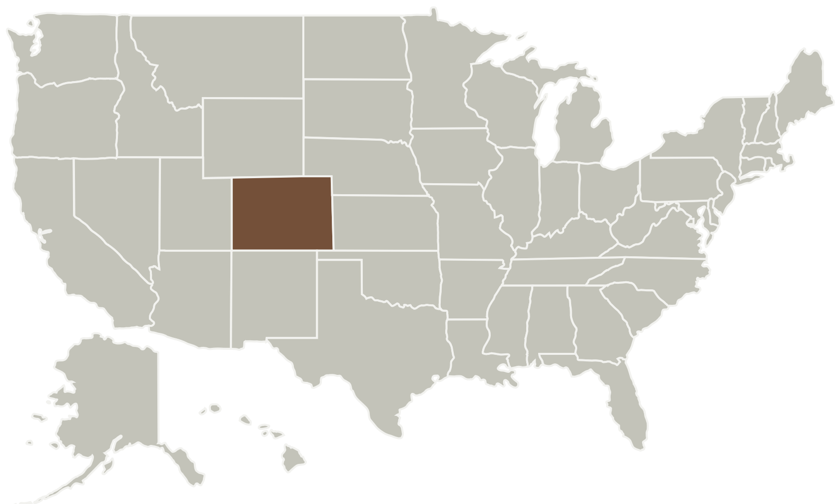
Laurence R Young
Christopher D Wickens
Charles W Oman

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
National Space Biomedical Research Institute(NSBRI)	Lead Organization	Industry	Houston, Texas
Alion Science And Technology Corporation	Supporting Organization	Industry	Boulder, Colorado
Massachusetts Institute of Technology(MIT)	Supporting Organization	Academia	Cambridge, Massachusetts

Primary U.S. Work Locations
Colorado

Project Transitions

September 2007: Project Start

Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - └ TX06.2 Extravehicular Activity Systems
    - └ TX06.2.3 Informatics and Decision Support Systems

Target Destinations

The Moon, Mars

August 2011: Closed out

Closeout Summary: Observer was 'packaged' as a DLL (dynamically linked library) within SDAT. SDAT users can select w hether they wish to use Observer algorithms for predicted perception, or SDAT's algorithms. While Observer may be more p hysiologically accurate, Observer requires data sets to be of a fixed rate and fairly high frequency (10-100 Hz). Unfortunate ly, actual vehicle flight data recordings rarely meet these requirements. In addition, Observer does not account for misperc eptions due to sub-threshold motions, which are critical to many SDAT illusion models. Therefore, we give users the option to select Observer or SDAT algorithms for attitude perception predictions. We designed three new illusion models to SDAT b ased upon vertical landing vehicle scenarios that we observed in data sets provided by an anonymous source of helicopter d ata -- data sets that included confirmed SD events. The three models are: (1) "Undetected loss of lift" which occurs when t he pilot unwittingly flies out of ground effect with insufficient thrust to maintain the new altitude, resulting in a sudden plun ge toward the surface; (2) "Inadvertent drift during hover" that could result in the vehicle striking an obstacle; and (3) "Un detected drift during landing" that could cause the vehicle to tip-over. SDAT has also been enhanced with a pilot attention model called N-SEEV. N-SEEV elevates applied countermeasures when SDAT predicts that the pilot is suffering from SD and has not attended to a lower level of countermeasures. We created an updated version of SDAT's user manual and delivered SDAT and its user manual to NSBRI. We did not undertake an experiment to validate the newly enhanced SDAT because we could use existing data sets plus the new ones acquired from our anonymous source of helicopter data sets. We also judged that a simulator validation experiment would use resources needed to do the best possible job of integrating Observer into SDAT. FORT tool cost scores are not integrated into SDAT because it is inappropriate to do so; they could be integrated into Observer. The FORT tool remains a separate stand-alone tool. We performed additional FORT tool validation, and submitted an article to the Human Factors Journal. We received 40 usable survey responses, analyzed the data from the 71 missions i n the responses, and submitted an article to Aviation, Space, and Environmental Medicine reporting our method and result s. We also sent de-identified data to our customer, NASA-JSC's Dr. Jacob Bloomberg, and will make the full set of de-identif ied data available to anyone who wishes it.

Stories

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Project Website:

https://taskbook.nasaprs.com